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Welcome to the interpretive webpage for the collaborative, multi-year research project, "Managing marine ecosystem responses to increasing nutrients and other disturbances: Herbivory as a response to algal overgrowth in two Hawai'i National Parks." This project was proposed and funded by the National Park Service (Department of the Interior) (http://www.nps.gov), and designed and executed in collaboration with the University of Hawai'i at Hilo, Marine Science Department (http://hilo.hawaii.edu/academics/marine-science/) and the Coral Reef Ecology Laboratory (http://coralreefecology.ucsd.edu/) at Scripps Institute of Oceanography.

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Project Summary

The marine National Parks in the state of Hawai'i generate a great deal of public attention by hosting an array of charismatic, endemic, threatened and endangered, ecologically important and culturally substantial coral reef species, including the Hawaiian monk seal (*Monachus schauinslandi,*'ilio holo i ka uaua) and the Hawaiian green sea turtle (*Chelonia mydas*, honu). In addition, Parks host more than twenty-five species of stony corals, which provide protective habitat for nearly all other coral reef inhabitants, and more than fifty species of endemic coral reef fish, including the rare bandit angelfish (*Apolemichthys arcuatus*), and the visually striking red flame wrasse (*Cirrhilabrus jordani*). As the coastal landscape of Hawai'i undergoes increasing changes due to development and usage, coral reef ecosystems face growing threats including increased harvest of reef fish and associated changes in ecosystem function, as well as increased exposure to anthropogenic nutrients and other pollutants.

Recent studies in Hawai'i have shown that increased coastal nutrient inputs can encourage nuisance algal growth and contribute to declines of local coral reef systems (Stimson et al. 2001, Smith and Smith 2006, Hunt 2007, Johnson et al. 2008, Parsons et al. 2008). However, where grazer density is sufficient, herbivory can regulate algal overgrowth. Our study investigates the bottom-up effects of benthic nutrient inputs (through submarine groundwater discharge) and the top-down effects of fish and invertebrate grazing on algal growth rate within two Hawai'i parks: Kaloko-Honokōhau National Historical Park (KAHO) and Kalaupapa National Historical Park (KALA). Sampling stations were randomly selected at each park and surveyed during summer months from 2011-2014. Project findings establish a baseline understanding of nutrient and herbivory interactions in the parks, and will help guide future management practices. Although the symptoms of change are apparent throughout the Caribbean and in some areas of Hawai'i, coral reefs in the national parks of Hawai'i are still relatively healthy, highlighting the urgency for informed management actions.

Keywords

Hawaiian coral reef, Hawaiian coral reef ecology, herbivory, grazing, parrotfish, *Chelonia mydas*, Hawaiian green sea turtle, honu, nutrients, submarine groundwater discharge, coastal groundwater seeps, coral reef phase shifts, benthic cover, benthic macroalgae, limu, *Sargassum echinocarpum*, limu kala, sea lettuce, *Ulva fasciata*, limu pālahalaha, wana, sea urchins, anthropogenic disturbance, coastal development, National Park Service, Kaloko-Honokōhau National Historical Park, Kalaupapa National Historical Park, Pacific Island Parks.

Project Objectives

Primary project objectives are: 1) to describe park coral reef site characteristics including benthic water quality, light and temperature, benthic cover, and algal turf standing stock, 2) to investigate the responses of algal communities to groundwater-associated benthic nutrient inputs, 3) to characterize the grazer community, and 4) to investigate the role of grazer communities in regulating algal growth.

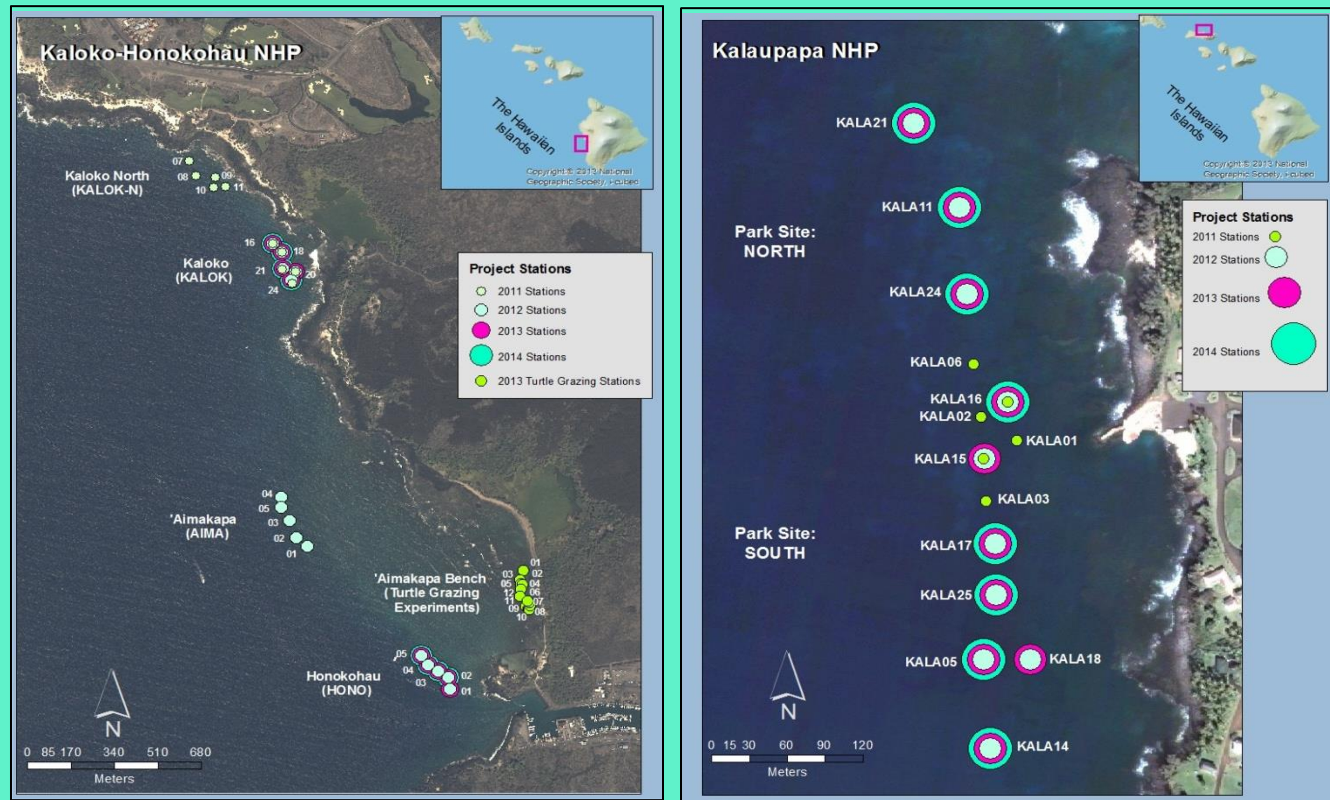
Specific research objectives investigated include: 1) characterizing benthic water quality, sampled at low tide to maximize groundwater presence, 2) describing light level and water temperature at each station, 3) describing current benthic cover and algal turf standing stock at each station, 4) estimating macroalgal growth under varying benthic nutrient regimes, 5) analyzing tissue nutrient content (∂15N, C:N:P) for macroalgal species *Ulva fasciata* and *Sargassum* spp. following seven-day deployments at benthic stations, 6) quantifying (visually and with unmanned video) the grazer community, including herbivorous fish, invertebrates and sea turtles, 7) comparing grazing rates, and 8) comparing algal turf growth when grazers are excluded or partially excluded from the reef substrate.

Study Sites

Project objectives were investigated at two marine National Parks in Hawai'i: Kaloko-Honokōhau National Historical Park located on the leeward coast of Hawai'i Island, and Kalauapapa National Historical Park located on the northern shore of Molokai Island (See Fig. 1, 2a).

Kaloko-Honokōhau National Historical Park (KAHO) is located in Kailua-Kona, on the west side of Hawai'i Island. Enabling legislation requires the preservation and perpetuation of traditional Native Hawaiian culture, which relies on adequate water quality within anchialine pools, fishponds, and coastal marine waters. The Park was established in 1978 and contains 626.7 acres of marine waters, including an extensive coral reef ecosystem spanning from Noio Point (south of Honokōhau Harbor) to Wahahiwa'a Point/ Kohana'iki. The marine environment hosts several threatened and endangered species, including the Hawaiian monk seal (*Monachus schauinslandi*), the Humpback whale (*Megaptera novaeangliae*) and the Hawaiian green sea turtle (*Chelonia mydas*).

Figure 1. Selected project sampling stations at Kaloko-Honokōhau NHP (left) and Kalaupapa NHP (right).



Like much of Hawai'i, Kaloko-Honokōhau NHP receives high volumes of submarine groundwater discharge (SGD), which can transport nutrient-laden freshwater to the marine environment. Increased exposure to coastal/upland development, semi-treated irrigation water, fertilizers, wastewater treatment-plant discharge, septic systems, cesspools, and storm runoff can significantly impact nutrient and pollutant loads entering park waters. These and other inputs may lead to significant habitat changes and ecosystem shifts, adversely impacting cultural practices, threatened and endangered species, and the coral reef ecosystem. Eutrophication is of growing concern at KAHO, and in 2008 as a result of nutrient concentrations consistently above state standards, Honokōhau Harbor and Honokōhau Beach (HI315174), in the southern portion of Kaloko-Honokōhau NHP, Pine Trees Beach (HI320616), and Pine Trees-Honokōhau (HIW00146), along the northern boundary, were designated as impaired under 303d of the federal Clean Water Act (DOH 2008, DOH 2012).

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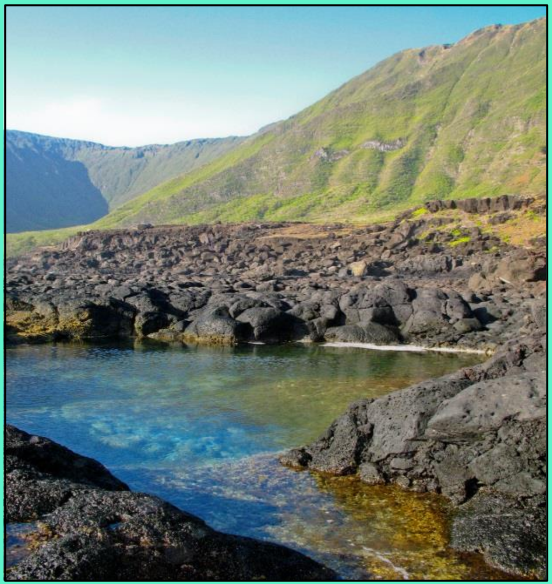

Figure 2a (above right). Kaloko-Honokōhau National Historical Park includes two fishponds (Kaloko, ‘Aimakapa), a fishtrap (‘Aiopio), and is adjacent to Honokōhau Harbor.
Figure 2b (above left). Tidepool collection site for algae used in project experiments, located in the Kalawao region of the Kalaupapa peninsula.

The Kalaupapa National Historical Park (KALA) (Fig. 1, 2b) is located on the northern peninsula of the Island of Molokai. The park was established in 1980, and contains 2000 acres of unconsolidated boulder/coral habitat. In contrast to the expansive coral reef at Kaloko-Honokōhau NHP, coral cover at Kalaupapa NHP is approximately 10-25% due to intensive wave energy. Like Kaloko-Honokōhau NHP, the park also supports three protected marine species, including including the Hawaiian monk seal (*Monachus schauinslandi*), the Humpback whale (*Megaptera novaeangliae*) and the Hawaiian green sea turtle (*Chelonia mydas*). Kalaupapa NHP is presently one of the largest Hawaiian monk seal pupping habitats in the Main Hawaiian Island (MHI). The relatively healthy nature of the Kalaupapa NHP marine environment can be partially attributed to its remote location and lack of surrounding development. Although relatively pristine, local water resource threats include inadequate local sewage treatment and upland agricultural activities.

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Methods

Detailed sampling methods for benthic water sampling, macroalgal growth experiments, nitrogen-isotope sampling (using sea lettuce, *Ulva fasciata*, limu pālahalaha), algal turf growth experiments, macro-grazer surveys, benthic cover analysis, and grazing assay experiments are available in the project Final Technical Report, available February 2014.

Figure 3. Research diver Camille Barnett surveys urchin and fish assemblages at Kalaupapa NHP (upper left). A demersal grazing assay (lower left). A benthic grazing assay (upper right). A typical benthic substrate photo-quadrat at Kaloko-Honokōhau NHP (lower right).

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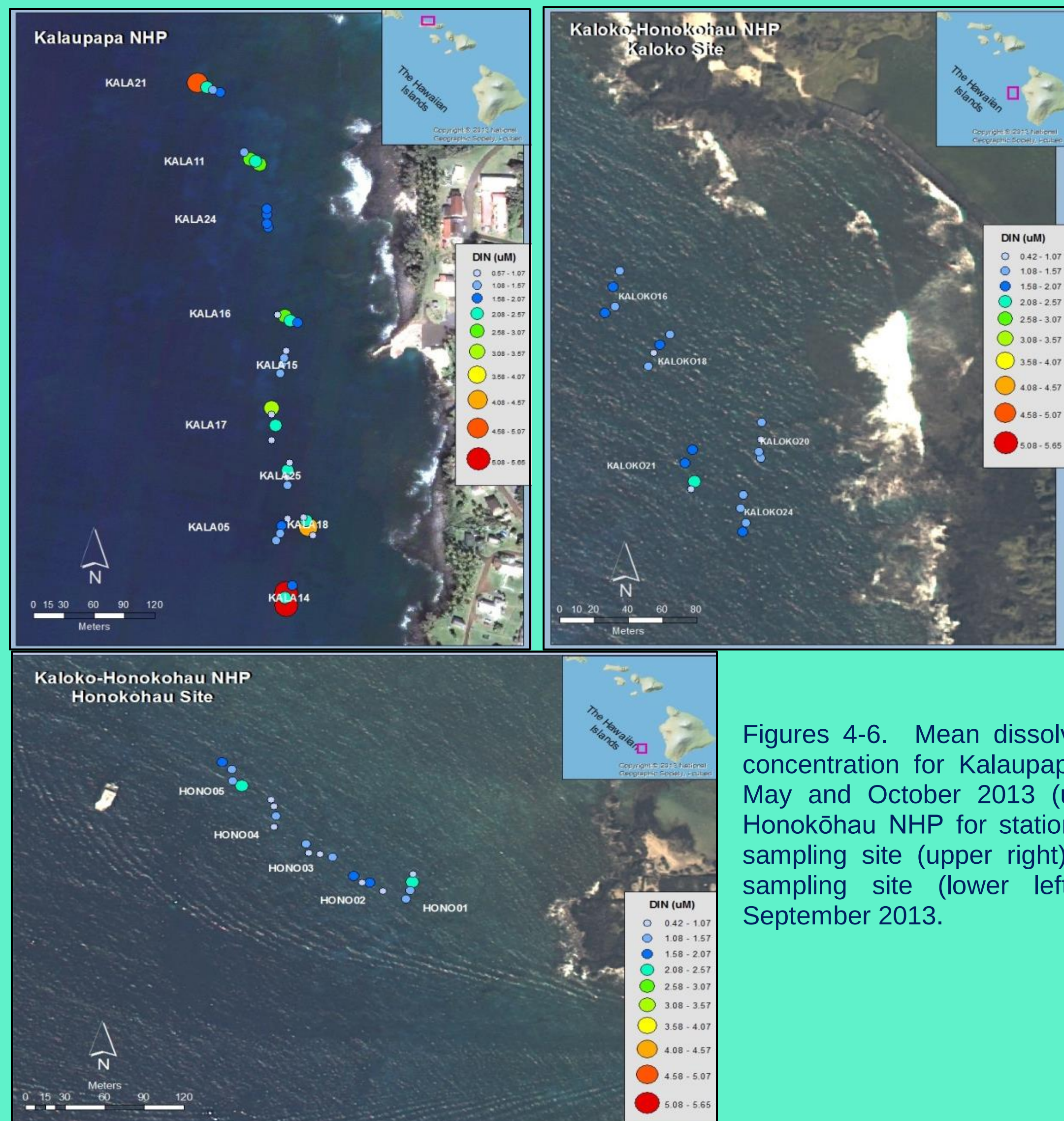
Project Findings

Findings: Dissolved benthic nutrients and groundwater seeps

Results from water sample analyses for benthic groundwater seep characterization are shown in Figures 4-6 for benthic dissolved inorganic nitrogen (DIN) concentrations observed in 2013 at both parks.



Figures 4-6. Mean dissolved inorganic nitrogen (DIN) concentration for Kalaupapa NHP stations sampled in May and October 2013 (upper left), and for Kaloko-Honokōhau NHP for stations located within the Kaloko sampling site (upper right) and within the Honokōhau sampling site (lower left) observed in June and September 2013.

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Water sample analyses completed in 2011 and 2012 included total nitrogen (TN), total phosphorus (TP), orthosilicic acid (H_4SiO_4), total organic carbon (TOC), nitrate + nitrite (NO_3^- + NO_2^-), ammonium (NH_4^+), and phosphate (PO_4^{-3}). Analyses in 2013 and 2014 included only dissolved inorganic nutrients (nitrate + nitrite (NO_3^- + NO_2^-), ammonium (NH_4^+), and phosphate (PO_4^{-3})). Significantly greater nitrate + nitrite was observed for Kaloko-Honokōhau NHP in 2013 ($p>0.003$), averaging 0.72 $\pm$ 0.04 µM at Kaloko-Honokōhau NHP and 0.52 $\pm$ 0.05 µM at Kalaupapa NHP. Nitrogen analyses in 2011 through 2014 indicated fine-scale heterogeneity (on the scale of meters), with nitrogen level varying widely along 25-meter transects at both parks. For some stations, water samples collected a few meters from one another had values that varied over 50% for both nitrate + nitrite and ammonium concentration. These results indicate substantial (and spatially/ temporally variable) levels of submarine groundwater discharge and benthic nutrient inputs at both parks.

Findings: Macroalgal growth (Grazers-excluded)

Seven-day growth rate experiment results for common macroalgal species, *Sargassum* spp. (limu kala), were compared between parks in 2012 and 2013. Growth assays were deployed within small mesh cages to prevent grazing. *Sargassum* spp. growth rate was significantly higher at Kalaupapa NHP relative to Kaloko-Honokōhau NHP for 2013 experiments, averaging 3.63 $\pm$ 0.15% tissue accumulation/day at Kalaupapa NHP, and 1.78 $\pm$ 0.12% tissue accumulation/day at Kaloko-Honokōhau NHP (Figure 7).

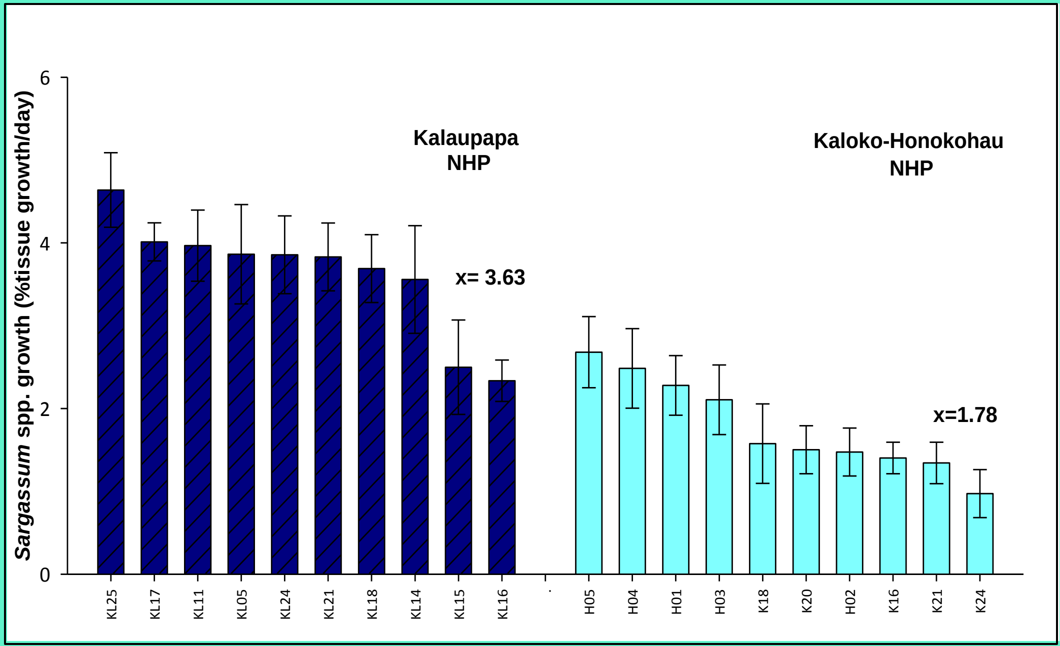

Figure 7. Macroalgal growth rate (% tissue accumulation/ day) for algal species *Sargassum* spp. observed in 2013 experiments at Kaloko-Honokōhau NHP and Kalaupapa NHP.

Findings: Benthic algal and coral cover

For most major benthic cover categories, percent cover varied significantly by park and often by park site (See Fig. 1 for park sites). Significantly higher stony coral cover (33.4 ± 5.2%, $p>0.0001$), crustose coralline algae (CCA) (11.5 ± 2.4 %, $p>0.0001$), and *Sarcothelia edmonsoni/Palythoa caesia* cover (0.54 ± 0.17%, $p>0.016$) was observed at Kaloko-Honokōhau NHP (Fig. 8). An intensively cropped (grazed) algal turf of *Sargassum obtusifolium* was observed at the majority of Kalaupapa NHP stations, with occasionally thicker stands in reefs areas more challenging for grazers to access. Benthic image analysis reflected this field observation, and significantly higher algal turf ($p>0.0001$) and macroalgal cover ($p>0.0001$) were observed at Kalaupapa NHP, with algal turf cover averaging 69.2 ± 3.3% at Kalaupapa NHP and 40.1 ± 3.5% at Kaloko-Honokōhau NHP. Macroalgal cover averaged 14.7 ± 2.7% at Kalaupapa NHP and 0.04 ± 0.12% at Kaloko-Honokōhau NHP.

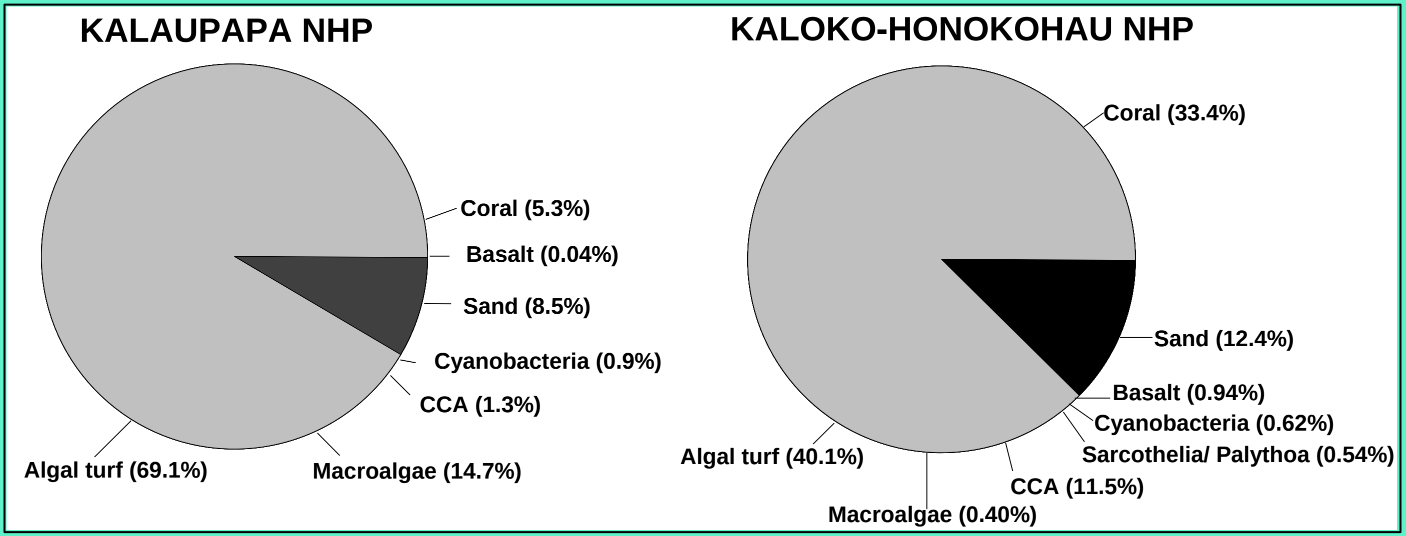

Figure 8. Percent cover of primary categories of benthic inhabitants at Kaloko-Honokōhau NHP and Kalaupapa NHP, based on Photogrid benthic images analysis for images collected along transects in 2011 and 2012.

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Findings: Algal turf growth with grazers-excluded (cage treatments)

The effects of abiotic factors (including benthic nutrients) on algal turf growth were quantified using herbivory exclusion substrate treatments (cages), which were placed over $10cm^2$ “natural substrate” plots. Plots were were hand cleared of all algae at the start of the experiment, and algal turf growth was quantified after approximately 60-days of grazer exclusion in 2011, 2012 and 2013, and after approximately 110-days of grazer exclusion in 2014. (Coral was never included in any $10cm^2$ plot or removed from the substrate.)

For 2013 experiments, algal turf growth was significantly higher at Kalaupapa NHP relative to Kaloko-Honokōhau NHP ($p<0.0001$), averaging 638.4 $\pm$ 46.4 at Kalaupapa NHP and 433.3 $\pm$ 22.0 at Kaloko-Honokōhau NHP (Fig. 9), suggesting relatively abiotically-enhanced (i.e., benthic dissolved nutrients) algal turf growth is occurring at Kalaupapa NHP.

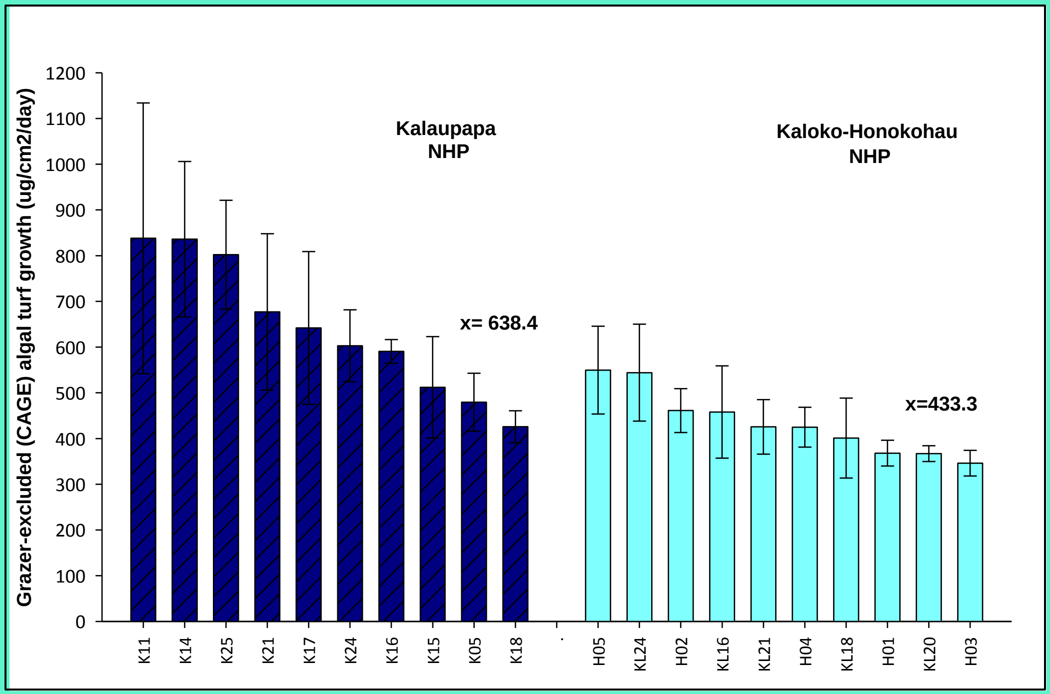

Figure 9. Algal turf growth within grazer-excluded plots (cage treatments), following 60-day grazer exclusion experiments in 2013 at both parks.

A comparison of algal growth within “caged” (grazer-excluded) plots and control plots open to all grazers indicated a strong grazer effect at KAHO for sampling years 2011 through 2013 (60-day trials), and a significant grazer effect at KALA for longer duration experiments (110 day) run in 2014. Storms damages to cage treatments in 2014 prevented analysis of the 120-day trials at KAHO. Grazer effects on algal growth are discussed below in, ‘Findings: Grazer effects on algal turf growth’.

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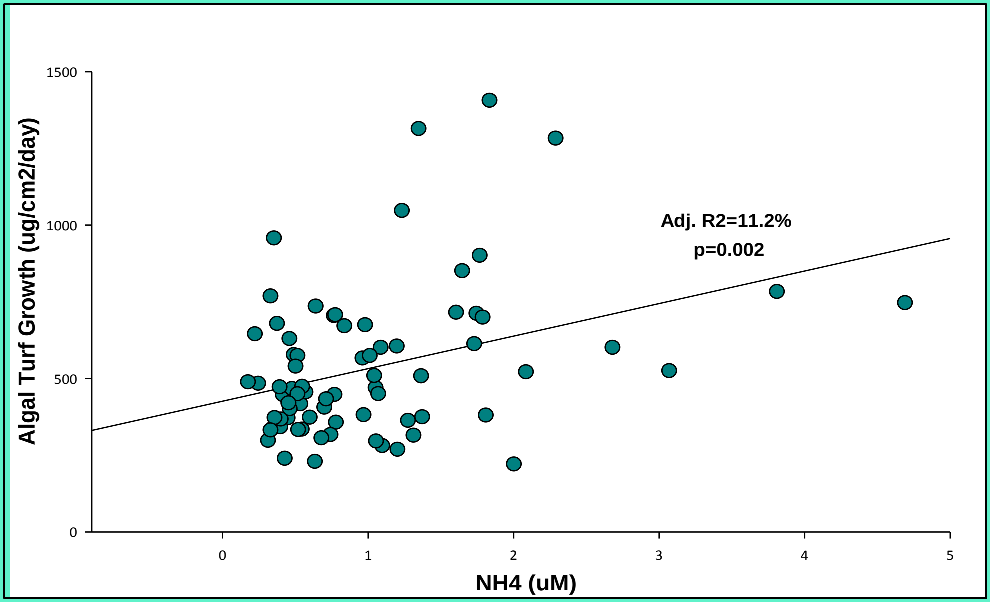
Regression analyses were used to compare benthic dissolved nutrient concentrations to algal growth within grazer-excluded (caged) treatments (Fig. 10-11). A significant positive relationship was detected between grazer-excluded (cage) algal turf growth and dissolved ammonium concentration ($NH4^{+}$), dissolved inorganic nitrogen (DIN), and dissolved phosphate ($PO4^{-3}$) concentration. As observed benthic nutrient concentration increased (for $NH4^{+}$, DIN, and $PO4^{-3}$) increased, algal Kaloko-Honokōhau NHP plots also increased.



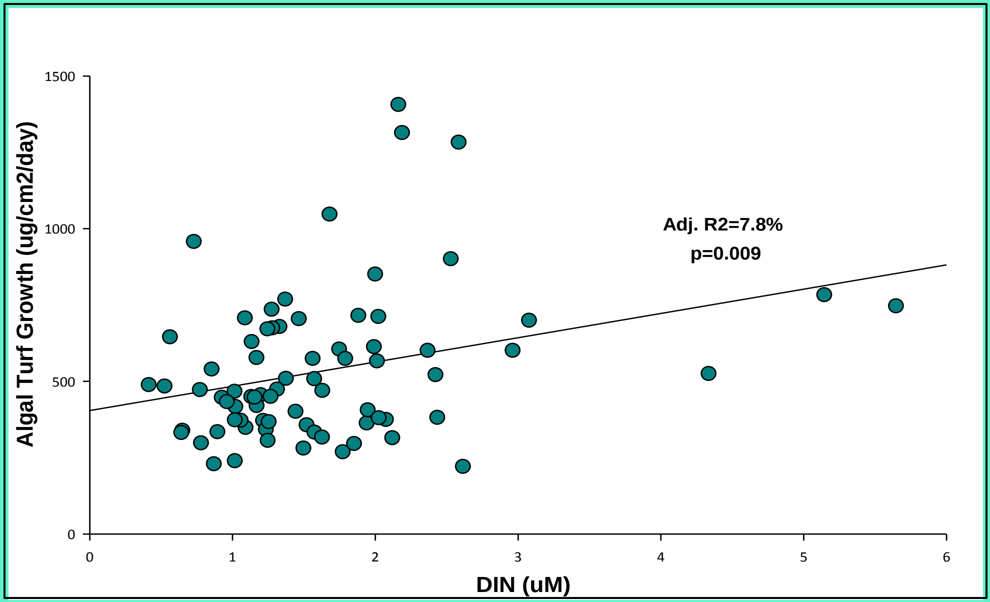


Figure 10-11. Results of regression analyses of algal turf growth in grazer-excluded (cage) treatments compared to dissolved benthic ammonium concentrations (top), and dissolved inorganic nitrogen concentration (bottom). Water samples were collected at low tide just above each grazer-excluded (cage) algal turf growth plot.

Findings: Grazer assemblages

Herbivorous fish and invertebrate species observed during project surveys are listed in Tables 1 and 2 below, and survey results are illustrated geographically in Figures 13-18. The most abundant herbivorous fishes observed at KALA included blue-spine unicornfish (kala, *Naso unicornis*), orange-spine unicornfish (umaumalei, *N. literatus*), brown surgeonfish (mā'i'i'i, *A. nigrofuscus*), and orange-band surgeonfish (na'ena'e, *A. olivaceous*) (Fig. 12). At KAHO, brown surgeonfish (mā'i'i'i, *A. nigrofuscus*), yellow tang (lau'īpala, *Zebrasoma flavescens*), and palenose parrotfish (uhu, *Scarus psitticus*) were the most commonly observed herbivorous fishes.

At KALA, urchin surveys were dominated by the substrate-boring urchin species, *Echinostrephus aciculatus*, which is not a prolific algal grazer (Table 1). *E. aciculatus* are thought to never leave its test-size hole, which it slowly excavates throughout its life (Hoover 1999). Somewhat similarly, the rock-boring urchin, *Echinometra mathaei*, dominated visual surveys at most KAHO stations. *E. mathaei* primarily grazes on algal turf within its excavated burrow, with substantially less grazing activity in the surrounding area. For this reason, urchin species were separated into two functional groups, 'roving grazers' and 'boring grazers' (Table 1). Grazing analyses focused on the more intense grazers included in the 'roving grazer' category.

Figure 12. A typical herbivorous fish assemblage at Kalaupapa National Historical Park, including common fish species included blue-spine unicornfish (kala, *Naso unicornis*), orange-spine unicornfish (umaumalei, *N. literatus*).

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Table 1. Observed sea urchin (Class: Echinoidea) species and functional groups included in project analyses.

Functional Group	Description	Urchin Species	Common Name	Hawaiian Name
ROVING GRAZER	Rove reef nocturnally to graze on benthic algae, Typically hide in natural substrate throughout day.	*Chondrocidaris gigantea*	Rough-spined urchin	
		Diadema paucispinum	Long-spined urchin	wana hālula
		Echinothrix calamaris	Banded urchin	wana
		Echinothrix diadema	Blue-black urchin	wana
		Eucidaris metularia	Ten-lined urchin	ha 'ue'ue
		Heterocentrotus mammillatus	Red pencil urchin	hā'uke'uke'ula'ula
		Pseudoboletia indiana	Pebble collector urchin	hāwa'e po'o hina
		Tripneustes gratilla	Collector urchin	hāwa'e maoli
BORER	Create protective habitat by boring into substrate, Graze bored 'tracks' and immediate surrounding area nocturnally.	*Echinometra mathaei*	Rock-boring urchin	'ina kea
		Echinometra oblonga	Oblong urchin	'ina
		Echinostrephus aciculatus	Needle-spined urchin	

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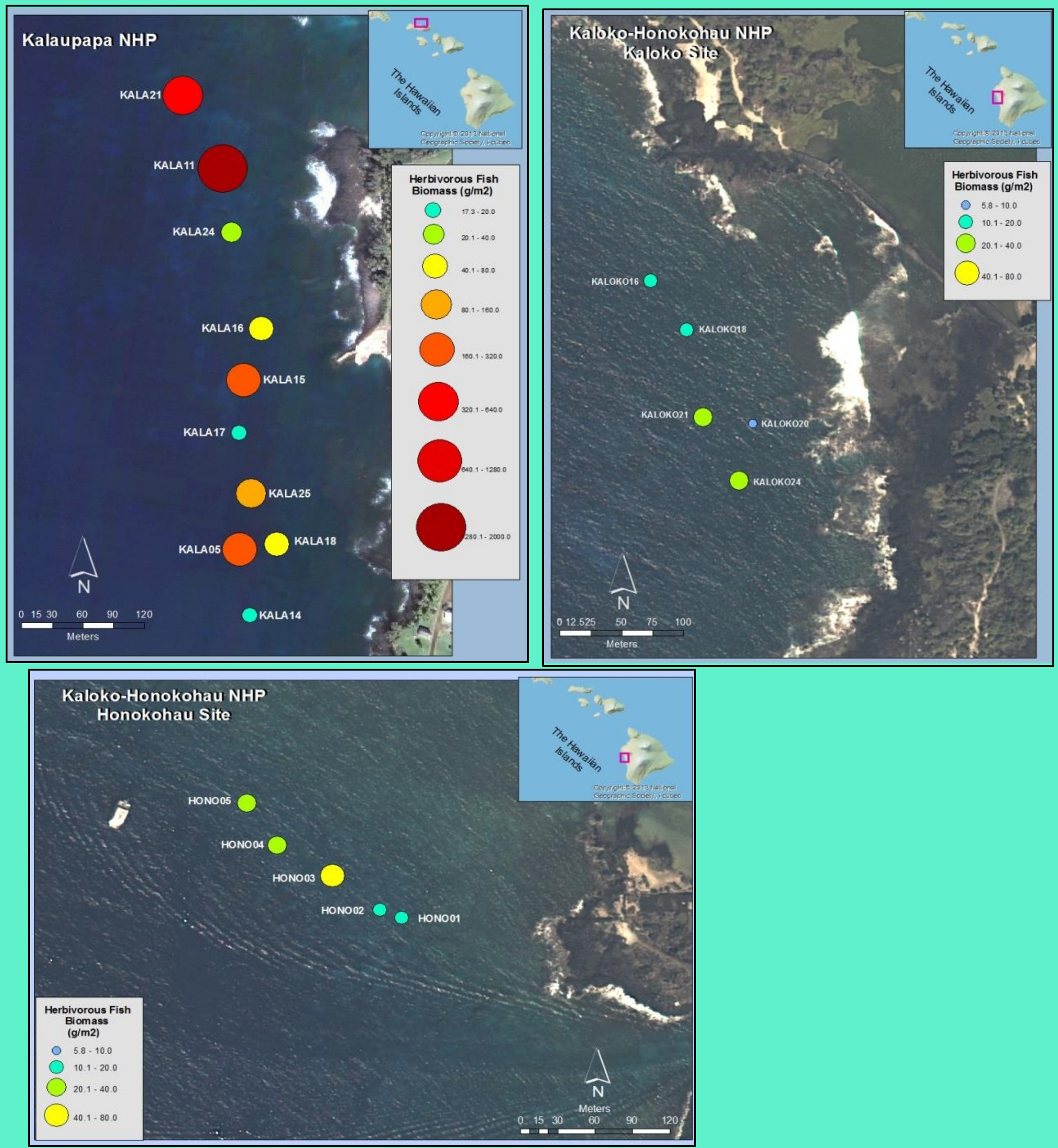
Table 2. Herbivorous fish species observed during park surveys. Species listed were included in the analysis of herbivorous fish biomass for each station. ‘Targeted Species’ indicates that the species is commonly fished or collected for the commercial aquarium trade.

Family	Species	Common Name	Hawaiian Name	Targeted Species	Family Diet Characteristics*
Acanthuridae (Surgeonfishes)	*Acanthurus blochii*	Ringtail surgeonfish	pualu	yes	Herbivorous: usually prefer benthic algae, sometimes zooplankton and detritus included in diet.
	Acanthurus dussumieri	Eyestripe surgeonfish	palani	yes	
	Acanthurus leucopareius	Whitebar surgeonfish	māikoiko	yes	
	Acanthurus nigrofuscus	Brown surgeonfish	mā'i'i'i	no	
	Acanthurus nigroris	Blueline surgeonfish	maiko	yes	
	Acanthurus olivaceus	Orangeband surgeonfish	na'ena'e	yes	
	Acanthurus triostegus	Convict tang	manini	yes	
	Naso lituratus	Orangespine unicornfish	umaumalei	yes/aquarium	
	Naso unicornis	Bluespine unicornfish	kala	yes	
	Zebrasoma flavescens	Yellow tang	lau'īpala	yes/ aquarium	
	Zebrasoma veliferum	Sailfin tang	māneoneo	yes	
Balistidae (Triggerfishes)	*Melichthys niger*	Black durgon	humuhumu 'ele 'ele	yes/aquarium	Herbivorous/ omnivorous: prefer benthic and drift algae, also zooplankton and small invertebrates.
	Melichthys vidua	Pinktail durgon	humuhumu hi'ukole	yes/aquarium	
Blennidae (Blennies)	*Cirripectes vanderbilti*	Scarface blenny	pāo'o	no	Herbivorous: diet of algae, sometimes benthic invertebrates.
Chanidae (Milkfish)	*Chanos chanos*	Milkfish	'awa	yes	Adults herbivorous: diet of benthic algae and invertebrates.
Kyphosidae (Sea Chubs)	*Kyphosus hawaiiensis*	Bicolor chub	nenue	yes	Herbivorous: prefer benthic plants and drift algae.
	Kyphosus sp.	Sea chub	nenue	yes	
Scaridae (Parrotfishes)	*Calotomus carolinus*	Stareye parrotfish	pōnuhunuhu	yes	Herbivorous: scrape algae from substrate. Bits of rock eaten with the algae are crushed into sand.
	Chlorurus splilurus	Bullethead parrotfish	uhu	yes	
	Scarus dubius	Regal parrotfish	lauia	yes	
	Scarus psittacus	Palenose parrotfish	uhu	yes	
	Scarus rubroviolaceus	Redlip parrotfish	uhu pālukaluka	yes	
Pomacanthidae (Angelfishes)	*Centropyge potteri*	Potter's angelfish		aquarium	Herbivorous: prefer filamentous algae.
Pomacentridae (Damselfishes)	*Stegastes marginatus*	Hawaiian gregory		no	Herbivorous: often defend algal territories and farm desired algae.
Tetraodontidae (Pufferfishes)	*Canthigaster amboinensis*	Ambon toby		no	Herbivorous/omnivorous: Prefer benthic plants and drift algae.
	Canthigaster jactator	Hawaiian whitespotted toby		no	

Figures 13-15. Observed herbivorous fish biomass during 2012 surveys at Kalaupapa NHP (upper left), Kaloko-Honokōhau NHP within the Kaloko sampling site (upper right), and at Kaloko-Honokōhau NHP within the Honokōhau sampling site (lower left).



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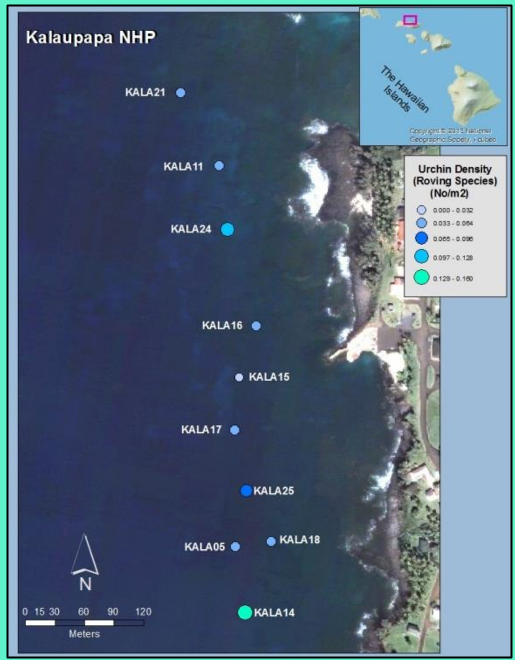
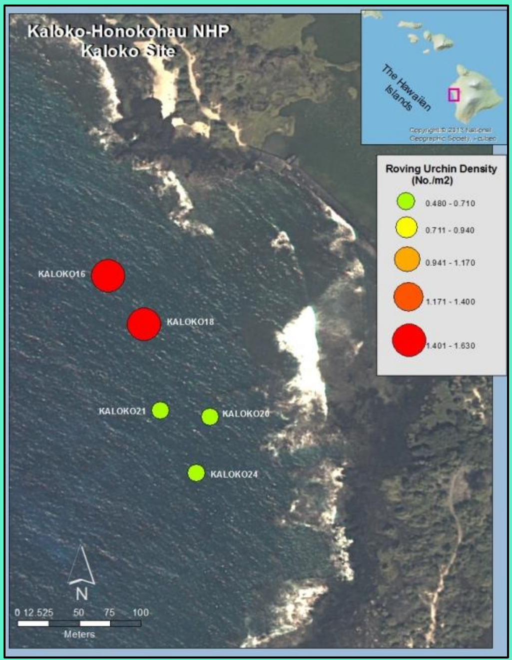
Total urchin densities were significantly higher at KAHO for both 'total urchins' and 'roving urchins' categories ($p < 0.0001$). At KAHO, total urchin density averaged 5.02 $\pm$ 0.38/m^2, and roving urchin density averaged 0.88 $\pm$ 0.09 /m^2. Roving urchins were rarely observed during visual surveys at KALA. Urchin density was significantly lower at KALA, with total urchin density averaging 1.19 $\pm$ 0.17/m^2 for total urchins and 0.05 $\pm$ 0.01 /m^2 for roving urchins (Figures 15-17).





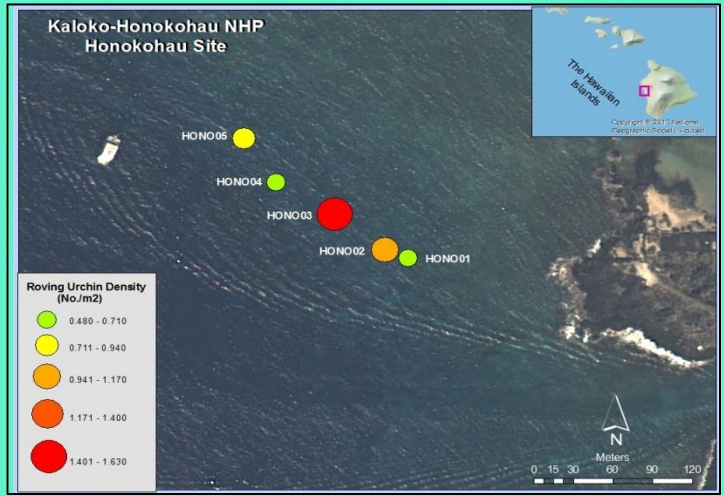


Figure 15-17. Observed roving urchin density during 2012 surveys at Kalaupapa NHP (upper left), at Kaloko-Honokōhau NHP within the Kaloko sampling site (upper right), at Kaloko-Honokōhau NHP within the Honokōhau sampling site (lower left)

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Findings: Grazing rates

Grazing rates were compared at KAHO and KALA using *Sargassum* spp. (limu kala) assays deployed for 18 hours at each station in 2013. A significantly higher grazing rate was observed at KAHO for both benthic and demersal assays ($p>0.0001$) (Fig. 18). Benthic grazing rate averaged 2.50 ± 0.11 % consumed/hour at KAHO, and 1.91 ± 0.13 % consumed/hour at KALA. Demersal grazing rate averaged 2.21 ± 0.01 % consumed/hour at KAHO, and 1.93 ± 0.13 % consumed/hour at KALA.

A significant positive relationship was observed for large, roving urchin density and benthic grazing rate ($p=0.014$), indicating that as urchin density increased, grazing rates along the benthos also increased.

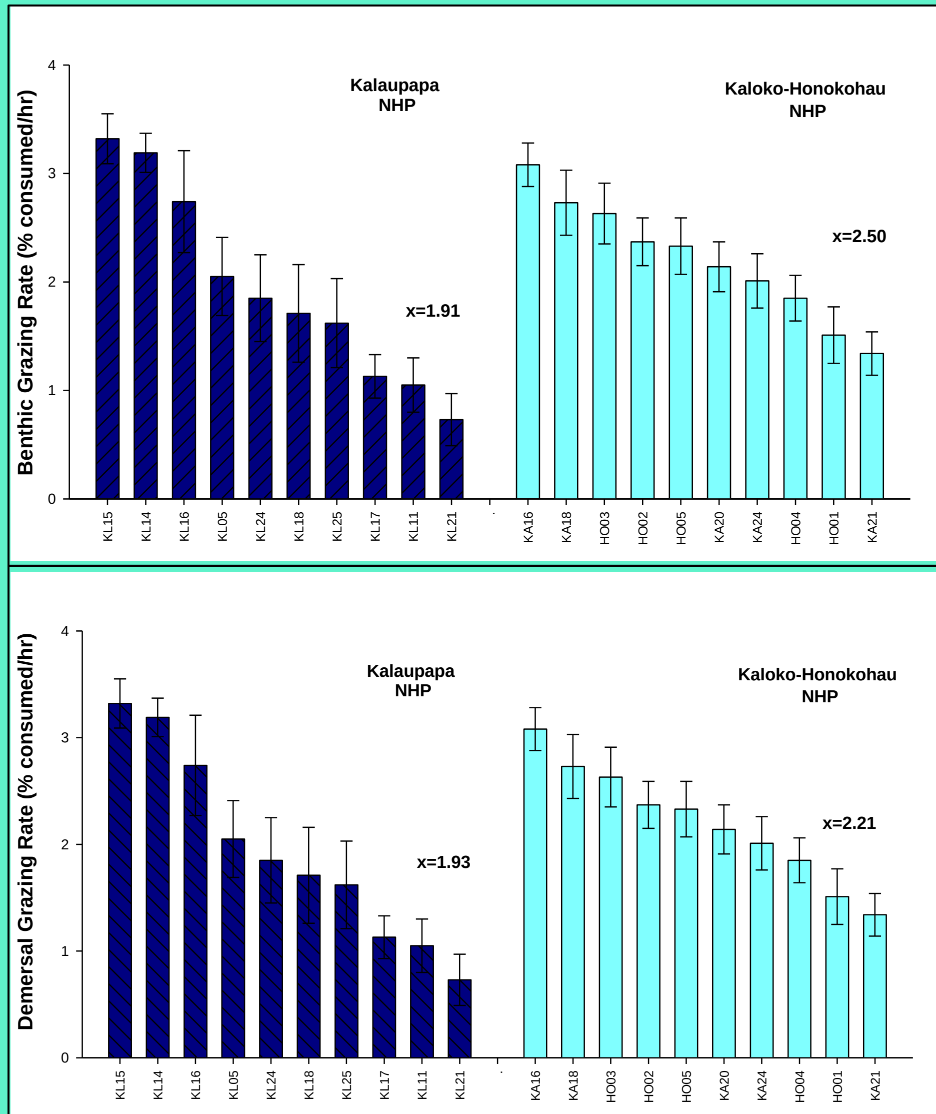

Figure 19.a,b. Benthic grazing rates (top), and demersal grazing rates (bottom) observed for assays of algal species *Sargassum* spp. (limu kala) deployed for 18 hours at both parks in summer 2013.

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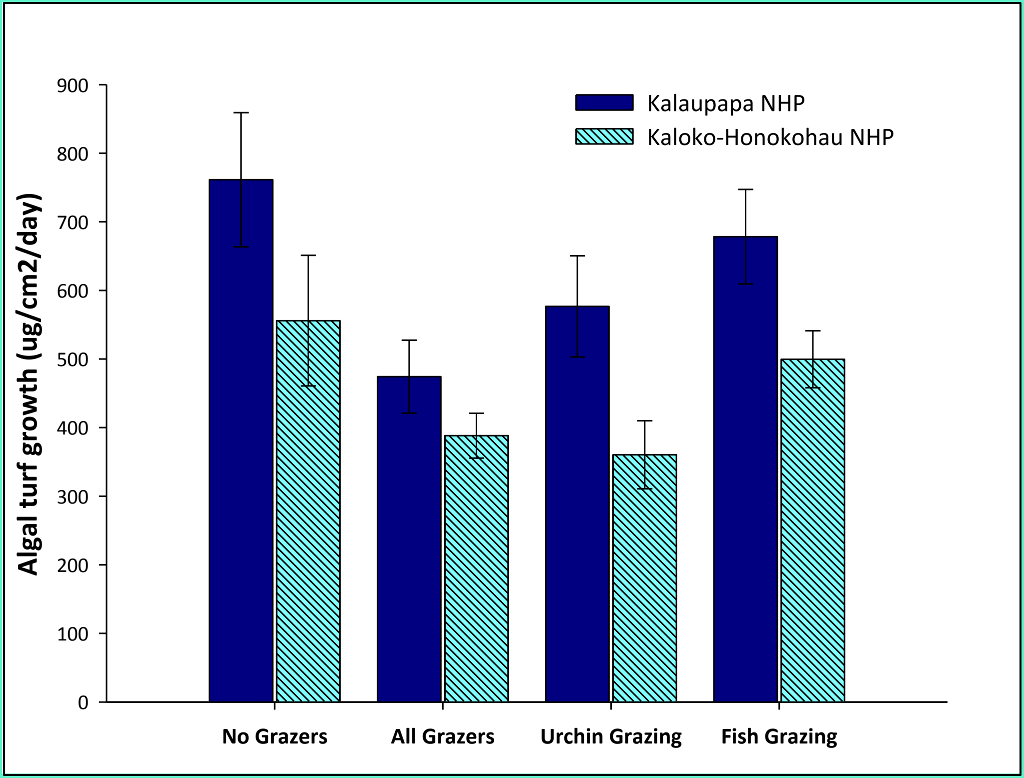
Findings: Grazer effects on algal turf growth

A comparison of grazer-excluded (caged) plot algal turf growth to control plots open to all grazing indicated a strong grazer effect at KAHO for project sampling years 2011-2013 (60-day trials), and a significant grazer effect at KALA for 2014 experiments (Fig. 20). At KAHO, growth within caged experimental plots was significantly higher than control plots open to grazing ($p>0.005$) for 2011-2014 experiments. At KAHO, the strongest grazer effects were associated with large, roving urchin grazers (canopy treatments), and a significant positive relationship was observed for large, roving urchin density and benthic grazing rate ($p=0.014$). As urchin density increased at KAHO, grazing rates along the benthos also increased. Higher densities of urchins observed at KAHO are resulting in observable higher benthic grazing rates on coral reefs at the park.



Algal turf growth at KALA was generally higher for all treatments relative to growth at KAHO. Turf growth was highest for grazer-excluded plots (cages) at KALA, and where grazers were allowed (open plots), algal turf growth was significantly reduced (Fig. 20). At both parks, coral reef grazers are playing an important role in controlling algal growth.

Figure 20. Algal turf growth rates ($\mu g/cm^2/day$) observed after 110-day deployments of herbivory exclusion cages, partial exclusions, and open controls. Results are shown for 2014 KAHO and KALA experiments.

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Findings: Shallow grazer effects on algal growth (intertidal)

In July 2013 and 2014, small wire grazer-exclusion cages were deployed along the shallow basalt bench just offshore of ‘Aimakapa Fishpond. Primary grazers in this area are assumed to be green sea turtles, *Chelonia mydas*. Using the methods described above replicate $10cm^2$ natural substrate algal turf growth plots were scraped clear by dive teams. Plots were located inside each cage (grazers excluded) or just outside (grazers allowed). Algal turf growth within each plot was sampled after 120 days in 2013 and after 60 days in 2014.

The results of 2013 turtle grazing experiments are shown in Figure 20. Algal turf growth was significantly higher within grazer-excluded (cage) treatment plots compared to control plots open to grazing ($p=0.035$), averaging 666.0$\pm$ 218.0 μg/cm2/day and 98.6$\pm$ 33.4 μg/cm2/day, respectively, indicating a strong grazer effect on algal turf growth. Shallow grazers (such as the Hawaiian green sea turtle, *Chelonia mydas*) are controlling shallow macroalgal growth at KAHO.

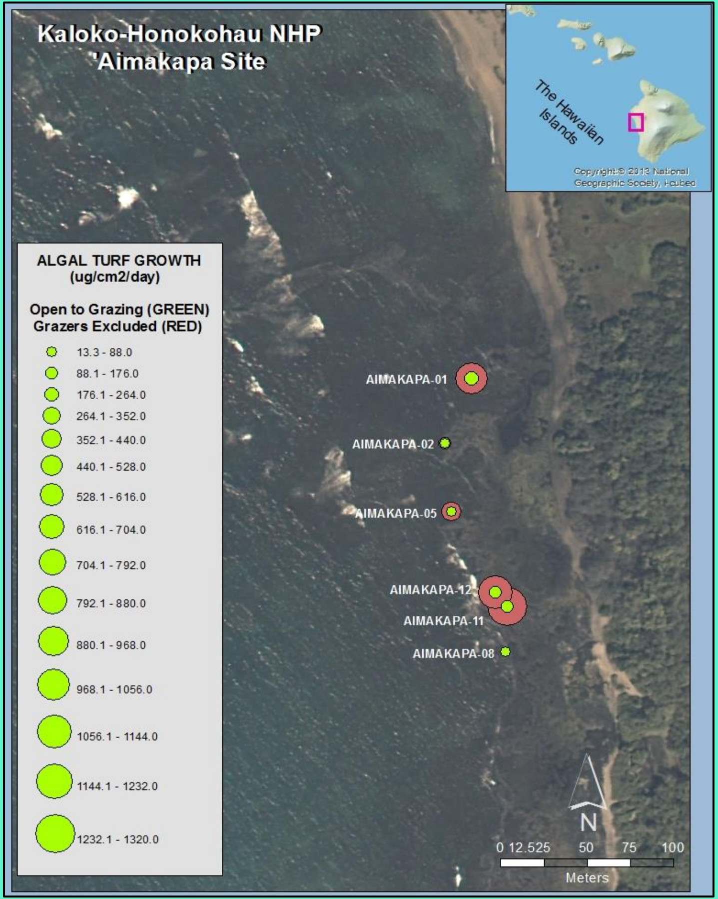

Figure 20. Experimental algal turf growth within shallow caged herbivory exclusion treatments at Kaloko-Honokōhau NHP. Experiments were run from July through October 2013. Stations are located in the shallow ‘Aimakapa sampling site at KAHO.

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Project scientists are currently reviewing and analyzing project findings to establish data-driven management recommendations. Please return to this website for updated information.

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2014 Final Technical Report *(Available February 2014)*

Acknowledgments

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